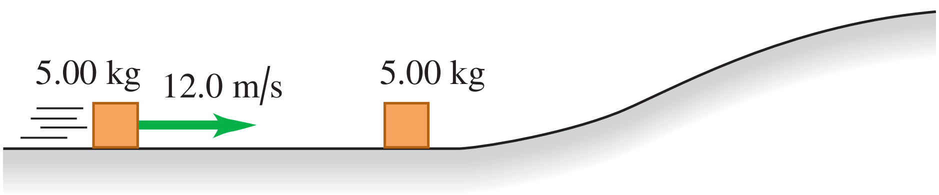
78 ••• **CP** A small wooden block with mass 0.800 kg is suspended from the lower end of a light cord that is 1.60 m long. The block is initially at rest. A bullet with mass 12.0 g is fired at the block with a horizontal velocity v_0. The bullet strikes the block and becomes embedded in it. After the collision the combined object swings on the end of the cord. When the block has risen a vertical height of 0.800 m, the tension in the cord is 4.80 N. What was the initial speed v_0 of the bullet?

79 •• **Combining Conservation Laws.** A 5.00-kg chunk of ice is sliding at 12.0 m/s on the floor of an ice-covered valley when it collides with and sticks to another 5.00-kg chunk of ice that is initially at rest. (Fig. P79). Since the valley is icy, there is no friction. After the collision, how high above the valley floor will the combined chunks go?

Figure **P79**



80 •• **Automobile Accident Analysis.** You are called as an expert witness to analyze the following auto accident: Car *B*, of mass 1900 kg, was stopped at a red light when it was hit from behind by car *A*, of mass 1500 kg. The cars locked bumpers during the collision and slid to a stop with brakes locked on all wheels. Measurements of the skid marks left by the tires showed them to be 7.15 m long. The coefficient of kinetic friction between the tires and the road was 0.65. (a) What was the speed of car *A* just before the collision? (b) If the speed limit was 35 mph, was car *A* speeding, and if so, by how many miles per hour was it *exceeding* the speed limit?

81 •• **Accident Analysis.** A 1500-kg sedan goes through a wide intersection traveling from north to south when it is hit by a 2200-kg SUV traveling from east to west. The two cars become enmeshed due to the impact and slide as one thereafter. On-the-scene measurements show that the coefficient of kinetic friction between the tires of these cars and the pavement is 0.75, and the cars slide to a halt at a point 5.39 m west and 6.43 m south of the impact point. How fast was each car traveling just before the collision?

8.78. **IDENTIFY:** An inelastic collision (the objects stick together) occurs during which momentum is conserved, followed by a swing during which mechanical energy is conserved. The target variable is the initial speed of the bullet.

SET UP: Newton's second law, $\Sigma\vec{F} = m\vec{a}$, will relate the tension in the cord to the speed of the block during the swing. Mechanical energy is conserved after the collision, and momentum is conserved during the collision.

EXECUTE: First find the speed v of the block, at a height of 0.800 m. The mass of the combined object is 0.812 kg. $\cos\theta = \frac{0.8\text{ m}}{1.6\text{ m}} = 0.50$ so $\theta = 60.0°$ is the angle the cord makes with the vertical. At this position, Newton's second law gives $T - mg\cos\theta = m\frac{v^2}{R}$, where we have taken force components toward the center of the circle. Solving for v gives $v = \sqrt{\frac{R}{m}(T - mg\cos\theta)} = \sqrt{\frac{1.6\text{ m}}{0.812\text{ kg}}(4.80\text{ N} - 3.979\text{ N})} = 1.272\text{ m/s}$. Now apply conservation of energy to find the velocity V of the combined object just after the collision: $\frac{1}{2}mV^2 = mgh + \frac{1}{2}mv^2$. Solving for V gives

$V = \sqrt{2gh + v^2} = \sqrt{2(9.8\text{ m/s}^2)(0.8\text{ m}) + (1.272\text{ m/s})^2} = 4.159\text{ m/s}$. Now apply conservation of momentum to the collision: $(0.012\text{ kg})v_0 = (0.812\text{ kg})(4.159\text{ m/s})$, which gives $v_0 = 281\text{ m/s}$.

EVALUATE: We cannot solve this problem in a single step because different conservation laws apply to the collision and the swing.

8.79. **IDENTIFY:** During the collision, momentum is conserved, but after the collision mechanical energy is conserved. We cannot solve this problem in a single step because the collision and the motion after the collision involve different conservation laws.

SET UP: Use coordinates where $+x$ is to the right and $+y$ is upward. Momentum is conserved during the collision, so $P_{1x} = P_{2x}$. Energy is conserved after the collision, so $K_1 = U_2$, where $K = \frac{1}{2}mv^2$ and $U = mgh$.

EXECUTE: *Collision*: There is no external horizontal force during the collision so $P_{1x} = P_{2x}$. This gives $(5.00\text{ kg})(12.0\text{ m/s}) = (10.0\text{ kg})v_2$ and $v_2 = 6.0\text{ m/s}$.

Motion after the collision: Only gravity does work and the initial kinetic energy of the combined chunks is converted entirely to gravitational potential energy when the chunk reaches its maximum height h above the valley floor. Conservation of energy gives $\frac{1}{2}m_{\text{tot}}v^2 = m_{\text{tot}}gh$ and $h = \frac{v^2}{2g} = \frac{(6.0\text{ m/s})^2}{2(9.8\text{ m/s}^2)} = 1.8\text{ m}$.

EVALUATE: After the collision the energy of the system is $\frac{1}{2}m_{\text{tot}}v^2 = \frac{1}{2}(10.0\text{ kg})(6.0\text{ m/s})^2 = 180\text{ J}$ when it is all kinetic energy and the energy is $m_{\text{tot}}gh = (10.0\text{ kg})(9.8\text{ m/s}^2)(1.8\text{ m}) = 180\text{ J}$ when it is all gravitational potential energy. Mechanical energy is conserved during the motion after the collision. But before the collision the total energy of the system is $\frac{1}{2}(5.0\text{ kg})(12.0\text{ m/s})^2 = 360\text{ J}$; 50% of the mechanical energy is dissipated during the inelastic collision of the two chunks.

8.80. **IDENTIFY:** During the inelastic collision, momentum is conserved but not mechanical energy. After the collision, momentum is not conserved and the kinetic energy of the cars is dissipated by nonconservative friction.

SET UP: Treat the collision and motion after the collision as separate events. Apply conservation of momentum to the collision and conservation of energy to the motion after the collision. The friction force on the combined cars is $\mu_k(m_A + m_B)g$.

EXECUTE: *Motion after the collision*: The kinetic energy of the combined cars immediately after the collision is taken away by the negative work done by friction: $\frac{1}{2}(m_A + m_B)V^2 = \mu_k(m_A + m_B)gd$, where $d = 7.15\text{ m}$. This gives $V = \sqrt{2\mu_k gd} = 9.54\text{ m/s}$.

Collision: Momentum conservation gives $m_A v_A = (m_A + m_B)V$, which gives

$$v_A = \left(\frac{m_A + m_B}{m_A}\right)V = \left(\frac{1500\text{ kg} + 1900\text{ kg}}{1500\text{ kg}}\right)(9.54\text{ m/s}) = 21.6\text{ m/s}.$$

(b) $v_A = 21.6\text{ m/s} = 48\text{ mph}$, which is 13 mph greater than the speed limit.

EVALUATE: We cannot solve this problem in a single step because the collision and the motion after the collision involve different principles (momentum conservation and energy conservation).

8.81. **IDENTIFY:** During the inelastic collision, momentum is conserved (in two dimensions), but after the collision we must use energy principles.

SET UP: The friction force is $\mu_k m_{tot} g$. Use energy considerations to find the velocity of the combined object immediately after the collision. Apply conservation of momentum to the collision. Use coordinates where $+x$ is west and $+y$ is south. For momentum conservation, we have $P_{1x} = P_{2x}$ and $P_{1y} = P_{2y}$.

EXECUTE: *Motion after collision*: The negative work done by friction takes away all the kinetic energy that the combined object has just after the collision. Calling ϕ the angle south of west at which the enmeshed cars slid, we have $\tan\phi = \dfrac{6.43\text{ m}}{5.39\text{ m}}$ and $\phi = 50.0°$. The wreckage slides 8.39 m in a direction 50.0° south of west. Energy conservation gives $\frac{1}{2} m_{tot} V^2 = \mu_k m_{tot} g d$, so

$V = \sqrt{2\mu_k g d} = \sqrt{2(0.75)(9.80\text{ m/s}^2)(8.39\text{ m})} = 11.1\text{ m/s}$. The velocity components are

$V_x = V\cos\phi = 7.13\text{ m/s}$; $V_y = V\sin\phi = 8.50\text{ m/s}$.

Collision: $P_{1x} = P_{2x}$ gives $(2200\text{ kg})v_{SUV} = (1500\text{ kg} + 2200\text{ kg})V_x$ and $v_{SUV} = 12\text{ m/s}$. $P_{1y} = P_{2y}$ gives $(1500\text{ kg})v_{sedan} = (1500\text{ kg} + 2200\text{ kg})V_y$ and $v_{sedan} = 21\text{ m/s}$.

EVALUATE: We cannot solve this problem in a single step because the collision and the motion after the collision involve different principles (momentum conservation and energy conservation).